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THE MIGRATIONS OF THE DESTRUCTIVE LOCUST  
OF THE WEST.

BY A. S. PACKARD, JR.

THE following remarks concerning the probable causes of the migrations of the western locust are extracted from a forthcoming report on this and other injurious insects in Prof. F. V. Hayden's Annual Report of the United States Geological and Geographical Survey of the Territories for 1875. The facts and theories were in part suggested by observations made by myself in Colorado, Utah, and Wyoming, in 1875, while attached for a few weeks to the Survey, and in part by the reports of Prof. C. V. Riley, State Entomologist of Missouri, and by the statements of Prof. Cyrus Thomas, State Entomologist of Illinois, and Hon. W. N. Byers of Denver, and others.

In dealing with this fearfully destructive insect, which has attracted so much notice from the public, and in seeking for remedies against its devastations, it is of prime importance to have a thorough knowledge of its breeding places, the frequency and extent of its migrations, and to seek for the connection between the direction of the winds and other meteorological phenomena, and the flights of the locust.

The locust is quite or nearly as destructive in Africa, Asia, and Southern Europe, as in this country, but the laws of their migrations and their connection with meteorological phenomena have never been studied in those regions, and it remains for the United States, with its Weather Signal Bureau, to institute in connection with the scientific surveys of the West investigations regarding the nature of the evil, and the best means to overcome it.

In endeavoring to trace the connection between the migrations of the locusts and the course of the winds at different months, the writer has been led into some theoretical considerations which seem to be supported by the facts presented in the unpublished report, and which may be confirmed or disproved by future investigations.

*History of the Migrations of the Locust.* — The following table, compiled from the reports of A. S. Taylor, the late Mr. B. D. Walsh, Prof. C. V. Riley, Prof. C. Thomas, Mr. G. M. Dawson, and the observations of Mr. W. N. Byers, will show the years when the locust was excessively abundant and destructive in the different territories and states, and also serve to roughly indicate the frequency and extent of the migrations of the destructive lo-

cust of the West. The dates which are starred are years when the progeny of the locusts of the preceding year abounded, and when in most cases there were no fresh incursions from the westward. The species referred to under the head of California, Washington, and Oregon may be some other than *Caloptenus spretus*.

Manitoba.	Minnesota and Western Iowa.	Montana and Dakota.	Wyoming and Idaho.	Utah.	Colorado.	Nebraska, Kansas, and Western Missouri.	Indian Territory and Texas.	California.	Washington and Oregon.
1818	1818								1827 or '28
1819	1819								1834 or '35
	1820					1820 or '21		1838	
			1845			1846 ?	1845		
			1852	1852			1849		1852
	1855	1855 ?	1855 ?	1855	1855 ?	1855	1855	1855	1855
	1856*			1856*			1856*	1856*	
1857				1857					
1864	1864	1864			1864				
					1865*				
						1866	1866		
1867	1867			1867	1867	1867	1867		
1868*				1868*	1868	1868*			
1869						1869*			
1872									
	1873	1873	1873	1873 ?	1873			1873	
1874	1874	1874	1874		1874	1874	1874	South.	
?	1875	1875	1875		1875*	1875*	1875	Cal.	
	1876	1876	1876		1876	1876	1876		

This table and the data on which it is based are necessarily very imperfect, owing to the vast extent of the territory over which the locust swarmed, and the fact that the greater portion is uninhabited, while the inhabited portions have been settled only within comparatively few years.

*The Theory of the Migrations.* — (1.) *The immediate cause of the migrations of the locust from its original breeding places is the unusual abundance of the species during certain years.* It has been found in some cases that the exceptional years when the locust migrates are periods of unusual heat and dryness, conditions unusually favorable to the excessive increase of insect life. As may be seen in the accounts of the eastern locust, the grass army worm, the grain aphid, the chinch bug, and other less destructive insects, when the early part of the season, the spring and early weeks of summer, are warm and dry, without sudden changes of temperature, insects abound and enormously exceed their ordinary numbers. When two such seasons occur, one after the other, the conditions become still more favorable for the undue

development of insect life. Now it is well known that in the Eastern States the summers of 1860 and 1874, preceding the appearance of the army worm and grain aphid, were unusually warm and dry, and favorable not only for the hatching of the eggs laid the year previous, but for the growth and development of the larvæ or young. Look now at the conditions for the development of locust life on the hot and dry plains, chiefly of Dakota, Montana, Wyoming, and Idaho. We have no meteorological records from these regions at hand, but it is more than probable that the years preceding the migrations of the locusts were exceptionally warm and dry, when the soil was parched with long-sustained droughts, as we know that the corresponding species east of the Mississippi River abounds during dry summers following dry and warm springs.

Given, then, the exceptional years of drought and heat and the great extent of territory, and we have as the result vast numbers of young hatched out. The year previous having perhaps been warm and dry, the locusts would abound, and more eggs than usual would be laid. These would with remarkably few exceptions hatch, and the young soon consume the buffalo grass and other herbage, and move about from one region to another, following often a determinate course in search of food. In this way large broods may migrate a long distance, from perhaps twenty to fifty miles. In about six or seven weeks they acquire wings. Experience shows that the western locust as soon as it is fledged rises up high in the air, sometimes a thousand feet or much higher. They have been seen to settle at night on the ground, eat during this time, and towards noon of the next day fill the air again with their glistening wings. As more and more become fledged, the vast swarm exhausts the supply of food, and when the hosts are finally marshaled, new swarms joining perhaps the original one, the whole swarm, possibly hundreds of miles in extent, begins to fly off, borne by the prevailing westerly and northwesterly winds, in a general easterly and southeasterly course.

(2.) *The secondary cause of the migration is the desire for food, and possibly the reproductive instinct.* The fact that in their migrations the locusts often seem to select cultivated tracts, rapidly cross the treeless, barren plains, and linger and die on the prairies and western edge of the fertile valleys of the Missouri and Mississippi, indicate that the impelling force is due primarily to the want of food, and that the guiding force is the direction

of the prevailing winds, for they have no leaders, and we do not believe in the existence of a "migratory instinct" in the locust any more than in the grass army worm, or the cotton army worm, which it is sufficiently evident migrate from field to field, simply in search of more abundant food. Meanwhile the reproductive system of the locusts is maturing, the eggs ripening, and the uneasiness of the locusts during the course of their travels may be unconsciously stimulated by the sexual instincts and the desire to discover suitable places for egg-laying, a long and tedious operation.

It has been sufficiently shown that a swarm of locusts observed by Professor Robinson near the entrance to Boulder Cañon, Colorado, traveled a distance of about six hundred miles to Eastern Kansas and Missouri. Though the swarm was first observed at some distance north of Denver, Colorado, it was then on its way from the north, and may have come from some part of Wyoming two or three hundred miles northwestward or northward. Though the winds may vary, and counter-currents exist, and storm-gusts from due north, such as often sweep over the plains, and local southerly breezes may retard their flight, the course is either eastward or southeasterly. We know enough of the winds in the Western States and Territories to lay down the law that the general direction of the winds in July and August, along the eastern slope of the Rocky Mountains and on the plains, is from the west and northwest, and accords with the eastward course of the locust swarms. The relations between the average direction of the winds and the migrations of the locust have, however, never been sufficiently studied, either, so far as we are aware, in Europe or in this country. And yet if we would intelligently study the causes of the excessive increase and migrations of the locust, we must examine the meteorological features of the country, ascertain the periods of drought and undue rain-fall, the average direction of the wind for the different months, in order to learn how far they correspond with the phenomena of insect life. That there are meteorological cycles, dry and hot seasons recurring at irregular intervals, while the general average may remain nearly the same century after century, is supported, though it may be vaguely, by observed meteorological facts.

The question then arises; *Can meteorologists predict the coming of seasons of undue heat and drought? and consequently can we predict insect years? that is, the migrations of locusts and the undue increase of the chinch bug, and army and cotton worm?* I

believe that we shall, after the lapse of years, be able to foretell with a good degree of certainty locust invasions, and be able to provide against the losses thus incurred.

On the frontier of the Western States, in Colorado, or in the Territories of Wyoming, Montana, and Utah, where the losses from the ravages of the locust cannot easily be made up by importations from contiguous territories, it seems the most practicable mode to provide in years of plenty against years of want. We should imitate on a grand scale the usage of the ancient Egyptians under Pharaoh, who laid up in times of unusual harvests stores of grain for times of famine. It is said that this has been done on a small scale by the Mormons. If this were done in the far West, in seasons immediately preceding insect years, which had been predicted by entomologists in conjunction with the meteorologists, we should be saved the distress, destitution, and even loss of life from starvation, which have resulted from ignorance of the laws regulating the appearance of destructive insects, especially the western locust.

*The Return Migration.*—By simultaneous observations for a number of years over the region liable to be visited by migratory hordes of locusts, added to the knowledge we already possess, it will not only be possible to predict the course of certain swarms from their breeding-places, and their probable destination, so that when a swarm starts from Montana or Wyoming, its arrival in Colorado a week or a fortnight later may with some certainty be predicted, and again, its arrival in Kansas and adjoining States be announced with a certain amount of precision, as has already been done by Dr. Riley, but we shall be able to foretell the course taken in the return flight of their progeny in the succeeding year. I will confess that previous to my visit to Kansas and Colorado, in 1875, I was skeptical as to Dr. Riley's opinion that there was a general movement in a northwest course of the young of the previous year, broods from Missouri and adjoining regions northwestward. The facts and resulting theory have already been stated in full by Dr. Riley and others. It remains to determine the causes of this return migration, this completion of the "migration-cycle," as Professor Dawson terms it. It is evident that in this case the desire for food is not the cause, for food is many times more abundant in the Mississippi Valley than on the plains whither they return. The solution of the problem, I think, must be sought in the direction of the prevailing winds during the middle of June, the time when they become winged.

It may be found after a series of careful meteorological observations, that the prevailing winds at this early season are southerly and southeasterly. It has been shown by meteorologists, as I learn from Prof. C. Abbe, that during May and June the winds blow inwards towards the heart of the continent from the Atlantic Ocean and Gulf of Mexico. On application to Gen. A. J. Myer, Chief of the Signal Service of the United States Army, for the meteorological data necessary to confirm this hypothesis, I promptly received a full summary of data observed by the officers of the Weather Signal Bureau, for periods of from two to five (usually the latter) years between 1871 and 1876, which show that the prevailing winds in June, in Davenport, Dodge City, and Keokuk, Iowa; Saint Paul and Breckenridge, Minnesota; Yankton and Fort Sully, Dakota; Omaha, Leavenworth, and Fort Gibson, Indian Territory, — all within the locust area, — are from the southeast and south. This fact may be sufficient to account for the prevailing course of the return migrations of the locust from the eastern limits of the locust area.

Let us therefore grant this setting-in of southerly and easterly winds, which may last until the locusts are winged. When they rise on the wing into the air they are known to move in a general northwest direction. It is highly probable that they are borne along by these generally southeasterly winds, and pass over on to the plains. The cause is seen, then, to be entirely independent of subsistence; possibly the reproductive instinct causes them to become uneasy, restless, to assemble high in the air and seek the dry, hot, elevated plateau of the northwest. Should this be so the cause of their migrations is probably purely mechanical. Abundant testimony is at hand to show that they are wholly at the mercy of the prevailing winds, and that as a rule the course of their migrations is quite dependent on the direction of the winds, while the course of the winds depend more or less on the season of the year. We may expect that future research over sufficient territory will show that the June migrations, from the eastern limits of the locust area, will be towards the northwest, and the July, August, and early September migrations, from the Rocky Mountain plateau, will be in a general easterly and southeasterly direction.

It is not only of great scientific interest, but of high practical importance, to collect all facts bearing on the return migrations, in order to know where the locusts go in their return migrations the second year, as we only know that they do fly a certain dis-

tance northwestward. We want to ascertain the extreme western limits of this return migration. We also want to learn whether they return to their original breeding-places on the eastern slopes of the Rocky Mountains, or whether the westerly winds, if they are westerly, drive them back and scatter them, so that they do not breed extensively.

It will be seen by the reader that all grounds for a reliable working theory of locust migrations are based on the work of our Signal Bureau and local observers, and that the observations of the meteorologists and entomologists must go hand in hand. The government has provided a well-organized corps of meteorological observers, and we submit that a number of competent entomologists should take the field, under government auspices. Not only should the border States, especially Texas, Kansas, Nebraska, Minnesota, and Iowa, employ competent entomologists, following the liberal policy of Missouri, which for eight years has had a state entomologist, whose reports have proved of incalculable practical value, as well as of great scientific interest, but the habits of the locust need first of all to be thoroughly studied in the Territories, particularly those of Wyoming, Montana, Idaho, Dakota, Utah, New Mexico, Arizona, and in the State of Colorado. A commission of entomologists should be appointed to make a thorough detailed study for several successive seasons of the habits of the locusts in the Territories mentioned. It would seem that the recommendations made at the recent meeting of Western governors at Omaha, that an appropriation be made by Congress, and a commission be attached to the existing United States Geological and Geographical Survey of the Territories, is the most feasible and economical method of securing the speediest and best results.

Let us for a moment look at the losses sustained in the United States from the attacks of insects. The annual agricultural products of this country by the last census amounted in value to \$2,500,000,000. Of this amount we in all probability *annually* lose over \$200,000,000 from the attacks of injurious insects alone. Dr. Riley avers that the losses during 1874 in Missouri from locusts, and it will be remembered that only the western third was invaded, exceeded \$15,000,000. This would make the losses in other parts of the West at least twice as much more, or \$45,000,000 in all. The estimated money loss occasioned by the chinch bug in Illinois in 1864 was over \$73,000,000; in Missouri in 1874, it is estimated by Dr. Riley to have been



\$19,000,000. The annual losses from the chinch bug are greater, Mr. Riley says, than from any other insect. The average annual loss to the cotton crop from the attacks of the cotton army worm alone is estimated at \$50,000,000. Adding to these the losses sustained by the attacks of about a thousand other species of insects which affect our cereals, forage and field crops, fruit trees and shrubs, garden vegetables, shade and ornamental trees, as well as our hard and pine forests, and stored fruits, and it will not be thought an exaggeration to put our annual losses at \$200,000,000. If the people of this country would only look at this annual depletion, this absolute waste, which drags her backward in the race with the countries of the Old World, they might see the necessity of taking effectual preventive measures in restraining the ravages of insects. With care and forethought based on the observance of facts by scientific men, we believe that from \$50,000,000 to \$100,000,000, or from one quarter to one half of this annual waste, could be saved to the country. And the practical, most efficient way is for the States to coöperate with the general government in the appointment of salaried entomologists, and of a United States commission of entomologists, who should combine the results of the state officials, and issue weekly, or, if necessary, daily bulletins, perhaps in combination with the Weather Signal Bureau, as to the conditions of the insect world, forewarning farmers and gardeners from week to week as to what enemies should be guarded against and what preventive and remedial measures should be used.

The Weather Signal Bureau, first suggested and urged by the late I. A. Lapham, was not instituted without ridicule and opposition, but it has saved millions to our commerce and agriculture. The maintenance of an entomological commission and the appointment of state entomologists would involve comparatively little expense. Already, owing to the full information regarding the invasion of Missouri by the locust in 1874, contained in the reports of Prof. C. V. Riley, the people of that State will be well prepared from the direful experience of the past, to deal more intelligently and efficiently with the locust in the future.